GLOBAL CHANGE

It's Official: First Glimmer of Greenhouse Warming Seen

A war of words among scientists and politicians warmed the air in Madrid last week, but the final words from an international panel of scientists assessing the state of climate science were cool and measured. Many uncertainties remain to be resolved, Working Group I of the Intergovernmental Panel on Climate Change (IPCC) concluded in a report* approved last week, but "nevertheless, the balance of evidence suggests that there is a discernible human influence on global climate."

A link between rising greenhouse gases, mainly carbon dioxide, and the global warming of the past century hasn't been proven unequivocally, notes atmospheric physicist Michael Oppenheimer of the Environmental Defense Fund in New York City, an IPCC contributor who was in Madrid. The scientists who prepared the relevant chapter are not yet certain that the half-degree warming isn't a natural fluctuation, notes Oppenheimer, in part because they don't know just how much climate varies on its own. These scientific uncertainties led to much debate over the exact phrasing of the conclusion—but the scientists' debate was tame compared to the wrangling among representatives of the governments assembled in Madrid. For example, oil-producing countries, mainly Saudi Arabia and Kuwait, argued long and hard for a retreat from the slightly stronger language of a draft report circulated in September (*Science*, 22 September, p. 1667).

Still, the final report announces that researchers now have a handle on the biggest problem in recognizing a human influence on climate—the disparity between the amount and geographic distribution of the warming predicted by climate models and the actual temperature records. The key was recognizing the cooling effect of the haze of fine particles that hangs over industrialized regions. This aerosol cooling alters the predicted "fingerprint" of the greenhouse effect by reducing the predicted warming and shifting its geographic pattern. More and more, the actual temperature record looks like this newly perceived fingerprint of human-induced climate change.

The first solid evidence that aerosols could be altering the signal of greenhouse warming came earlier this year when researchers reported data indicating that aerosols have cooled the climate of eastern North America, Europe, and south Asia in recent decades (*Science*, 12 May, p. 802). An aerosol-induced pattern of cooling, it seemed, must be superimposed over the greenhouse-warming pattern. So modelers fed both greenhouse gas increases and the effects of aerosols into the latest global climate models, which couple a model of the atmosphere to an ocean model complete with shallow and deep currents. They then used new, more sophisticated statistical techniques to gauge the similarities between the observed patterns and those predicted by the models. The first results seemed to show hints of the predicted greenhouse-plus-aerosols fingerprint (*Science*, 16 June, p. 1567).

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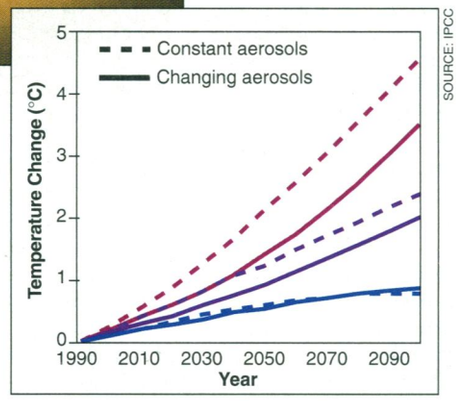

SOURCE: IPCC

Hazy outlook. In three different climate-change scenarios *(colors)*, increases in pollutant hazes *(inset)* moderate the warming.

By now, four next-generation studies from three research centers—Lawrence Livermore National Laboratory, Hadley Center for Climate Prediction and Research in Bracknell, United Kingdom, and the Max Planck Institute for Meteorology in Hamburg, Germany—have been published. All four studies, three of which focus on surface temperatures and one on temperatures aloft, show that over recent decades the observed spatial pattern of temperature change increasingly resembles the expected greenhouse-aerosol pattern. Says climate modeler Gerald Meehl of the National Center for Atmospheric Research: "It's really encouraging that when we add aerosols [to model simulations] we do start to see better agreement with the [climate] patterns we've already observed."

Other runs of the same computer models, done without increases in greenhouse gases or aerosols, suggest that this greenhouse fingerprint is not likely to be a chance fluctuation of the climate system. As predicted by the models, the natural variability of an undisturbed climate system looks different, statistically speaking, from the observed pattern of change. To bolster their quantitative studies a bit, the IPCC scientists also note a half-dozen different climate trends such as cooling of the stratosphere, increases in high-latitude precipitation, and rising sea levels that are all expected in a greenhouse-warmed climate—and have all been observed.

Still, the careful phrasing of the IPCC's conclusion reflects a range of opinion in the climate community. At one end is climatologist Tom Wigley of the University Corporation for Atmospheric Research in Boulder, Colorado, one of the four co-authors of the detection chapter. Speaking for himself last July at an IPCC session of an international meeting, Wigley made a stronger statement about human influence: "We can claim, with a high statistical confidence, to have identified an anthropogenic signal in the observed temperature record."

Climatologist Tim P. Barnett of Scripps Institution of Oceanography, also a co-author on the detection chapter, isn't so sure. He agrees that "we've moved closer to a point where you can say you've detected it for sure," but he emphasizes some of the caveats stated in the report itself. "I've worked with some of these coupled models, and they have some serious problems," says Barnett, including "flux corrections" that artificially keep them from drifting into unrealistic climate simulations (*Science*, 9 September 1994, p. 1528).

The models do behave well in the short run, he notes: "On annual to almost decadal time scales, we're finding the models do things that happen in nature," successfully predicting El Niños and their effects on climate, for example. But they haven't consistently reproduced longer records of climate change—for example, the temperature changes seen in this century, in which a sharp global warming was followed by a plateau from the 1940s through the 1970s and then by renewed warming. Barnett is concerned that the natural ups and downs in global temperature over such long periods may be larger than the models are suggesting, leading the more optimistic researchers to mistake natural fluctuations for greenhouse warming.

The report doesn't put that concern to

* Working Group I report of the Intergovernmental Panel on Climate Change. Contact Bruce Callander, bacallander@email.meto.govt.uk

rest. But it does answer some criticisms raised by greenhouse contrarians. For example, critics had noted that climate models, even with aerosols included, did not predict the faster warming at night relative to daytime that was being observed (*Science*, 7 February 1992, p. 683). Now the report notes that climate modeler James Hansen of the Goddard Institute for Space Studies in New York City and his colleagues have gotten their model to reproduce the nighttime warming by combining rising greenhouse gases and aerosols and an increase in cloud cover—a phenomenon widely observed but poorly understood.

In another controversial area, the IPCC report rejects the claim that satellite monitoring shows just one quarter of the warming predicted by climate models. The problem with that claim, says the report, is that the greenhouse skeptics are making comparisons with the wrong model simulations—ones that had greenhouse gases rising more rapidly than has happened so far or that weren't designed to gauge temperature increases in the first place. The latest models, incorporating aerosols and a realistic rise in greenhouse gases, predict 0.08° to 0.30°C of warming per decade, which puts the satellite warming rate of 0.09°C per decade just within the predicted range. Even that comparison may not be meaningful, notes the report, given the variability of global climate from decade to decade and the short, 16-year satellite record.

Just what effect the emerging scientific consensus will have on policy-making remains to be seen. For one thing, even though scientists have spotted a human hand in climate change, they still can't say how large its effects will be in the future. "Our ability to quantify the magnitude of this effect is presently limited," cautions the IPCC report, which gives estimates that range from a mild 1°C warming by 2100 to a hefty 3.5°C.

Still, Oppenheimer believes that the new IPCC finding "increases the likelihood that a real schedule of real [greenhouse gas] emission reductions" will come out of current negotiations being conducted under the 1992 Climate Convention. For now, industrialized nations have made a commitment to reduce their emissions to 1990 levels by 2000, but they are not strictly bound to do so.

In the United States, where the Republicans in Congress oppose many environmental regulations, the IPCC report could affect the thinking of the more moderate among them, says Robert Watson, associate director for environment in the White House's Office of Science and Technology Policy. It may "give them pause and make them think very carefully. It supports the contention that this is an issue that merits serious action." But as Oppenheimer notes with some understatement, "The politics of the details will not be easy."

–Richard A. Kerr

EARTH SCIENCE

Missing Chunk of North America Found in Argentina

Half a billion years ago, North America was a lost continent. Present-day Africa, Australia, Antarctica, South America, and India had assembled into the supercontinent of Gondwana, but North America and a few smaller continental fragments were drifting on their own, and geologists have had few clues to their peregrinations.

"The big issue in the paleogeography of the world about [that] time ... was the geography of the biggest players in this game, North America and Gondwana," says geologist Ian Dalziel of the University of Texas, Austin. But at a meeting of the Geological Society of America last month in New Orleans, speakers described how a chunk of crust in western Argentina is turning out to be North America's calling card. Dropped off in western South America nearly 500 million years ago, it pins down the errant North America to within a few thousand kilometers of South America's west coast. That's a big surprise, because it puts North America on the opposite side of Gondwana from the position it occupied in earlier, tentative paleogeographic reconstructions.

The revision may turn out to be important to researchers trying to understand "all these fantastic evolutionary things [that] were happening" at the time, says Dalziel, who first proposed the new geography. An evolutionary explosion was generating many of the life forms we know today, and the arrangement of drifting continents would have shaped such critical environmental factors as climate and sea level. The Argentine connection also provides a reference point for paleomapmakers as they ponder how all the continents, including North America, eventually gathered into a single supercontinent, Pangea, which formed about 250 million years ago.

Dalziel says he began suspecting that North America might once have lurked off the west coast of South America in 1991, when Eldridge Moores of the University of California, Davis, proposed how the continents might have been arranged in an even earlier supercontinent, called Rodinia, 750 million years ago. Moores suggested on the basis of geological similarities that Australia and Antarctica abutted the west coast of the ancestral North American continent, Laurentia, which lay at the core of Rodinia.

Dalziel, who had been thinking along the same lines, recalls that he then wondered how North America could have made its way "from somewhere adjacent to Antarctica to the position within Pangea that we know it had to have had." Taking into account such clues to Laurentia's wanderings as traces of Earth's ancient magnetic field frozen into its rocks, Dalziel plotted a meandering half-billion-year journey. The route took Laurentia on an "end run" around the west coast of South America to its final position in Pangea, where it collided with northwest Africa, pushing up the Appalachians. In mid-trip, according to a refinement offered by Luis Dalla Salda and his colleagues at the National University of La Plata, Argentina, the present eastern side of Laurentia ran smack into the coast of South America, right where the Andes rose hundreds of millions of years later.

At the GSA meeting, three speakers offered partial support for Dalziel's scenario. They confirmed that about 490 million years ago Laurentia and South America had been, if not in contact, close enough to exchange an 800-kilometer-long chunk of plate. First, William Thomas of the University of Kentucky explained how in 1991 he had inferred from U.S. geology alone that about 540 million years ago, a block of Laurentian crust had split away from what is now the Gulf Coast, never to return. At the time, he says, he had no idea where it might have gone.

The answer came in the second talk. The scheduled speaker, Ricardo Astini of the National University of Córdoba, Argentina, could not attend, but Thomas and Robert Hatcher of the University of Tennessee, the

SOURCE: ASTINI *ET AL.*

Gone south. During a close encounter between continents, a chunk of ancient North America migrated to South America.